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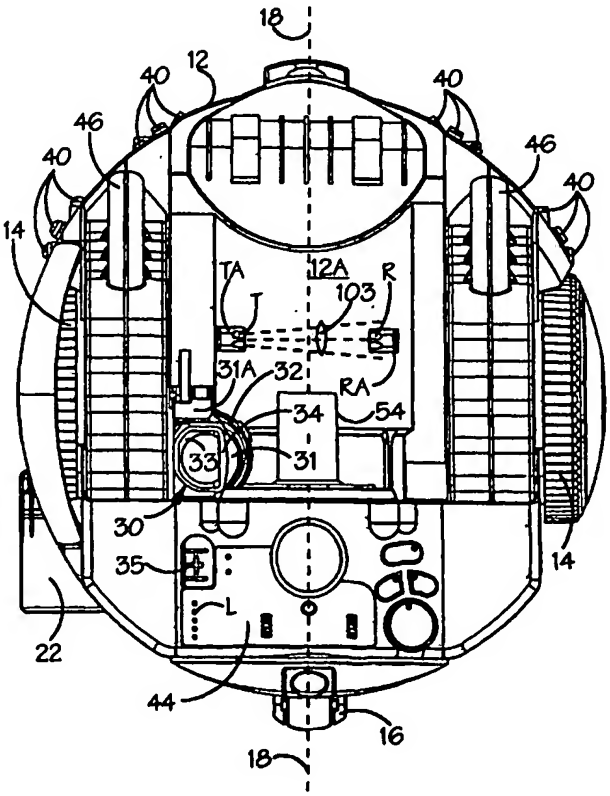

(57) Abstract: A vacuum cleaner (10) comprises a dirty air inlet (24), a cleaned air outlet, an airflow path extending between the inlet and outlet, a dirt and dust separator (52) positioned in the airflow path, a suction fan (50) for drawing air along the airflow path from the dirty air inlet (24) to the clean air outlet via the dirt and dust separator (52), and a device (T, R) for detecting and indicating when the amount of dirt collected in the dirt and dust separator (52) has reached or exceeded a predetermined level. The detecting device comprises an optical transmitter (T) and an optical receiver (R), the optical transmitter (T) and optical receiver (R) being located on the housing of the cleaner (10) at opposite ends of an optical path (103) extending through the wall of the dirt and dust separator (52).

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Vacuum Cleaner

This invention relates to a vacuum cleaner and particularly, but not exclusively, to a robotic vacuum cleaner.

Conventionally a vacuum cleaner has a bin or bag for retaining the dust and dirt collected during vacuuming. The cleaner has a fan and drive motor which draws the dirty airstream through the bin or bag and the dust and dirt are separated therein by, for example, a filtering membrane or by cyclonic action. The separated dirt and dust is deposited and retained in the bag or bin. It is important that the user recognizes when the bin or bag is full of dust and dirt and empties the bin or changes the bag, otherwise poor vacuuming efficiency will result and/or more dust and dirt than is desirable will be re-entrained into the airflow and subsequently emitted back into the atmosphere.

It is an object of the present invention to improve the operation of a vacuum cleaner and to minimize the amount of dust and dirt emitted back into the atmosphere during use of the cleaner, even after the cleaner has been used for some considerable time.

Accordingly, a first aspect of the present invention provides a vacuum cleaner comprising a dirty air inlet, a cleaned air outlet, an airflow path extending between the inlet and outlet, a dirt and dust separator positioned in the airflow path, a suction fan for drawing air along the airflow path from the dirty air inlet to the cleaned air outlet via the dirt and dust separator, a housing for supporting the separator and a device for detecting and indicating when the amount of dirt collected in the dirt and dust separator has reached or exceeded a predetermined level, wherein the device comprises an optical transmitter for generating an optical beam and an optical receiver, the optical transmitter and optical receiver being located on the housing at opposite ends of an optical path extending through the wall of the dirt and dust separator.

This has the advantage of minimising the risk of the vacuum cleaner operating under unacceptable conditions, e.g. by emitting more than an acceptable level of dust back into the atmosphere. The user of such an appliance is thereby able to leave the appliance to operate in the intended manner without needing to return to the appliance periodically to check whether the dirt and dust container requires to be emptied. Nor is there any risk that the appliance will become full and continue to operate at a reduced performance level, which could lead to dissatisfaction on the part of the user and frustration that the area thought to be clean must be cleaned again. By locating the optical transmitter and receiver on the housing rather than the separator itself, these components are protected from damage and fouling which could occur in use or when the separator is emptied. This also has a further advantage that there is no requirement for an optical or electrical connection between the housing and the separator which would be prone to wear and fouling.

Preferably, the optical transmitter and optical receiver are positioned close to spaced-apart portions of the dirt and dust separator.

More preferably, the dirt and dust separator comprises a cyclonic separator, advantageously comprising a container in which the dirt and dust separated from the airflow by the cyclonic separator is collected, and the container has transparent or translucent walls adjacent the optical transmitter and the optical receiver. The cyclonic separator can comprise two cyclones arranged in series, each cyclone having a separate container in which dirt and dust separated by the respective cyclone is collected, and the optical path of the device can be arranged to pass through only one of the said containers.

Preferably, the signal is either audible or visual. In addition, or as an alternative, the signal can comprise the step of shutting down the suction fan.

The invention is particularly appropriate for use with autonomous vacuum cleaners which operate unsupervised so that the automatic sensing of the overfilling of the dirt and dust container is important to maintain a high standard of vacuuming efficiency.

A second aspect of the invention provides a method of operating a vacuum cleaner comprising a dirty air inlet, a cleaned air outlet, an airflow path extending between the inlet and outlet, a dirt and dust separator positioned in the airflow path, a suction fan for drawing air along the airflow path from the dirty air inlet to the cleaned air outlet via the dirt and dust separator, a housing for supporting the separator and a device for detecting and indicating when the amount of dirt collected in the dirt and dust separator has reached or exceeded a predetermined level, the device comprising an optical transmitter and an optical receiver located on the housing, the method comprising the steps of passing an optical beam through the wall of the dirt and dust separator, detecting a change in the optical beam indicative of a predetermined level of collected dirt and dust having been reached or exceeded in the separator and providing to the user an indication of the predetermined level having been reached or exceeded.

Preferably, the step of detecting a change in the optical beam indicative of a predetermined level of collected dirt and dust having been reached or exceeded in the separator comprises the detection of a break in the optical beam which persists for a predetermined period of time. The predetermined period of time can advantageously be between 5 and 20 seconds, more preferably substantially 10 seconds.

An embodiment of the present invention will now be more particularly described with reference to the following drawings, in which:-

Figure 1 is a perspective view of a robotic vacuum cleaner according to the invention;

Figure 2 is a vertical section through the axis 18 of Figure 1;

Figure 3 is a plan view of the cleaner of Figure 1 with the cyclonic separator removed;

Figure 4 is a block diagram of the power management system and bin full detector of the vacuum cleaner of Figures 1 to 2;

Figure 5 is a vertical section of part only of the bin 62 and chassis 12 in a plane through the transmitter T and receiver R, of the cleaner, and;

Figures 6A, 6B and 6C show schematically alternative arrangements for the transmitter T and receiver R.

Referring to Figure 1 of the drawings, there is shown a robotic vacuum cleaner 10 having a supporting chassis 12 which is generally circular in plan view and is supported on two driven wheels 14 and a castor wheel 16 (Figure 2). The chassis 12 provides support for the components of the cleaner 10. The driven wheels 14 are arranged at either end of a diameter of the chassis 12, the diameter lying perpendicular to the longitudinal axis 18 of the cleaner 10. The driven wheels 14 are mounted independently of one another and are each connected directly to a respective motor (not shown) which is capable of driving the respective wheel 14 in either a forward direction or a reverse direction. By driving both wheels 14 forward at the same speed, the cleaner 10 can be driven in a forward direction. By driving both wheels 14 in a reverse direction at the same speed, the cleaner 10 can be driven backwards. By driving the wheels 14 in opposite directions, the cleaner 10 can be made to rotate about its own central axis so as to effect a turning manoeuvre. Other turning manouevres can be effected by driving one wheel only or by driving both wheels at different speeds. The aforementioned method of driving a vehicle is well known and will not therefore be described further here.

The castor wheel 16 is not driven and merely serves to support the chassis 12 at the rear of the cleaner 10. The castor wheel 16 is swivelingly mounted on the chassis by means of a swivel joint 20.

Referring to Figure 2, mounted on the underside of the chassis 12 is a cleaner head 22 which includes a suction opening 24 facing the surface on which the cleaner 10 is supported. The suction opening 24 is essentially rectangular and extends across the majority of the width of the cleaner head 22. A brush roller 26 is rotatably mounted in the suction opening 24 and a motor 28 is mounted on the cleaner head 22 for driving the brush roller 26 by way of a drive belt (not shown) extending between a shaft of the motor 28 and the brush roller 26. The cleaner head 22 is mounted on the chassis 12 in such a way that the cleaner head 22 is able to float on the surface to be cleaned. This is achieved in this embodiment in that the cleaner head 22 is pivotally connected to an arm (not shown) which in turn is pivotally connected to the underside of the chassis 12. The double articulation of the connection between the cleaner head 22 and the chassis 12 allows the cleaner head 22 to move freely in a vertical direction with respect to the chassis 12. A flexible conduit connection indicated generally by reference numeral 30 (Figure 3) is located beneath a cyclonic separator 52 (to be described in detail below) and above the cleaner head 22. It provides a telescopic air transfer conduit between the cleaner head 22 and the cyclonic separator 52 and comprises a short transfer conduit 31, an outlet 33 on the cleaner head 22 and a rolling annular seal 32 sealingly connected therebetween. A lip seal 34 is sealingly connected to the upper end of transfer conduit 31 and abuts an inlet port (not shown) of the cyclonic separator 52. A hooked catch 31A also carried by the transfer conduit 31 cooperates with a corresponding portion of the inlet port so as to lock the removable cyclonic separator 52 in place and this connection can be unlocked by pressing down on a rod (not shown) operated by button 35. When the cleaner head 22 moves upwardly with respect to the chassis 12, the rolling seal 32 distorts or crumples to accommodate the upward movement of the cleaner head 22. When the cleaner head 22 moves downwardly, the rolling seal unfolds or extends into an extended position to accommodate the downward movement. The inlet port of the cyclonic separator 52 is coupled to the tangential inlet of the cyclonic separator 52. The flow of air from the cleaner head 22 into the cyclonic separator 52 is

represented by the arrow A in entry portion 58A of the cyclonic separator 52 shown in Figure 2.

The vacuum cleaner 10 includes a motor and fan unit 50 supported on the chassis 12 for drawing dirty air into the vacuum cleaner 10 via the suction opening 24 in the cleaner head 22. The chassis 12 also carries the cyclonic separator 52 for separating dirt and dust from the air drawn into the cleaner 10. The cyclonic separator 52 comprises an outer cyclone 58 and an inner cyclone 56 arranged concentrically therewith, both cyclones 58,56 being coaxial with axis 18 and lying horizontally. The outer cyclone 58 includes the entry portion 58A which communicates with the cleaner head 22 via the inlet port as discussed earlier. The entry portion 58A is generally cylindrical and has an end wall 60 which is generally helical. The entry portion 58A opens directly into a cylindrical bin 62 having an outer wall 64 whose diameter is the same as that of the entry portion 58A. The cylindrical bin 62 is made from a transparent plastics material to allow a user to view the interior of the outer cyclone 58 and to facilitate operation of the bin-full detector, which will be described later. The end of the bin 62 remote from the entry portion 58A is frustoconical in shape and closed. A locating ring 66 is formed integrally with the end of the bin at a distance from the outer wall 64 thereof and a dust ring 68 is also formed integrally with the end of the bin 62 inwardly of the locating ring 66. Located on the outer surface of the bin 62 are two opposed gripper portions 70 which are adapted to assist a user to remove the separator 52 from the chassis 12 for emptying purposes. Specifically, the gripper portions 70 are moulded integrally with the transparent bin 62 and extend upwardly and outwardly from the outer wall 64 so as to form an undercut profile as shown in Figure 1.

The inner cyclone 56 is formed by a partially-cylindrical, partially-frustoconical cyclone body 72 which is rigidly attached to the end face of the entry portion 58A. The cyclone body 72 lies along the longitudinal axis 18 of the transparent bin 62 and extends almost to the end face thereof so that the distal end 72A of the cyclone body 72 is surrounded

by the dust ring 68. The gap between the cone opening at the distal end 72A of the cyclone body 72 and the end face of the bin 62 is preferably less than 8mm.

A fine dust collector 74 is located in the bin 62 and is supported by the locating ring 66 at one end thereof. The fine dust collector 74 is supported at the other end thereof by the cyclone body 72. Seals 76 are provided between the fine dust collector 74 and the respective support at either end. The fine dust collector 74 has a first cylindrical portion 74A received within the locating ring 66, and a second cylindrical portion 74B having a smaller diameter than the first cylindrical portion 74A. The cylindrical portions 74A,74B are joined by a frustoconical portion 74C which is integrally moulded therewith.

A single upright fin or baffle 78 is moulded integrally with the fine dust collector 74 and extends radially outwardly from the second cylindrical portion 74B and from the frustoconical portion 74C.

A shroud 80 is located between the first and second cyclones 58 and 56. The shroud 80 is cylindrical in shape and is supported at one end by the entry portion 58A and by the cyclone body 72 of the inner cyclone 56 at the other end. As is known, the shroud 80 has perforations 82 extending through it and a lip 83 projecting from the end of the shroud 80 remote from the entry portion 58A. A channel 84 is formed between the shroud 80 and the outer surface of the cyclone body 72, which channel 84 communicates with a tangential or scroll entry portion 60A into the inner cyclone 56. As can be seen from arrow C, this forces the airflow to adopt a swirling helical path.

The vortex finder 54 is located centrally at the larger end of the inner cyclone 56 to conduct air out of the cyclonic separator 52 after separation has taken place. The exiting air (arrow B) is conducted past the motor of unit 50 so that the motor is cooled before the air is expelled to atmosphere. Additionally, a post motor filter (not shown) can be

provided downstream of the motor and fan unit 50 in order to further minimize the risk of emissions into the atmosphere from the vacuum cleaner.

As mentioned earlier, the entire cyclonic separator 52 is releasable from the chassis 12 in order to allow emptying of the outer and inner cyclones 58 and 56. When the hooked catch 31A is released by manual pressing of the button 35 located in the control panel 44, the cyclonic separator 52 can be lifted away from the chassis 12 by means of the gripper portions 70. The bin portion 62 can then be released from the entry portion 58A (which carries with it the shroud 80 and the inner cyclone body 72) to facilitate the emptying thereof.

The chassis 12 carries a plurality of movement control sensors 40 which are designed and arranged to detect obstacles in the path of the cleaner 10 and its proximity to, for example, a wall or other boundary such as a piece of furniture. The sensors 40 comprise several ultrasonic sensors and several infrared sensors. The array illustrated in the Figures is not intended to be limitative and the arrangement of the sensors does not form part of the present invention. Suffice it to say that the vacuum cleaner 10 carries sufficient sensors and detectors 40 to enable the cleaner 10, through the electronic circuitry, to guide itself or to be guided around a predefined area so that the said area can be cleaned. Control software, comprising navigation controls and steering devices, is housed within a housing 42 located beneath a control panel 44. Battery packs 46 are mounted on the chassis 12 inwardly of the driven wheels 14 to provide power to the motors for driving the wheels 14, to the motor for driving the brush roller 26 and to the control software. The battery packs 46 are removable to allow them to be transferred to a battery charger (not shown).

The vacuum cleaner 10 described above operates in the following manner. In order for the cleaner 10 to traverse the area to be cleaned, the wheels 14 are driven by the motors 15 which in turn are powered by the batteries 46. The direction of movement of the cleaner 10 is determined by the control software which communicates with the sensors

40 which are designed to detect any obstacles in the path of the cleaner 10 so as to navigate the cleaner 10 around the area to be cleaned. Methodologies and control systems for navigating a robotic vacuum cleaner around a room or other area are well documented elsewhere and do not form part of the inventive concept of this invention. Any of the known methodologies or systems could be implemented here to provide a suitable navigation system.

The batteries 46 provide power to operate the motor and fan unit 50 to draw air into the cleaner 10 via the suction opening 24 in the cleaner head 22. The motor 28 is also driven by the batteries 46 so that the brush bar 26 is rotated in order to achieve good pickup, particularly when the cleaner 10 is used to clean a carpet. The dirty air is drawn into the cleaner head 22 and conducted to the cyclonic separator 52 via the telescopic conduit 30. The dirty air then enters the entry portion 58A in a tangential manner and adopts a helical path by virtue of the shape of the helical wall 60. The air then spirals down the interior of the outer wall 64 of the bin 62 during which motion any relatively large dirt and fluff particles are separated from the airflow. The separated dirt and fluff particles are collected in the end of the bin 62 remote from the entry portion 58A.

The airflow from which large dirt and larger fluff particles has been separated moves inwardly away from the outer wall 64 of the bin 62 and travels back along the exterior wall of the fine dust collector 74 towards the shroud 80. The presence of the shroud 80 helps to prevent larger particles and fluff traveling from the outer cyclone 58 into the inner cyclone 56, as is known. The air from which comparatively large particles and dirt have been separated then passes through the shroud 80 and travels along the channel between the shroud 80 and the outer surface of the inner cyclone body 72 until it reaches the scroll entry 60A of the inner cyclone 56. The air then enters the inner cyclone 56 in a helical manner and follows a spiral path around the inner surface of the cyclone body 72. Because of the frustoconical shape of the cyclone body 72, the speed of the airflow increases to a very high value at which the fine dirt and dust still entrained within the airflow is separated therefrom. The fine dirt and dust separated from the inner cyclone

56 is collected in the fine dust collector 74 outwardly of the dust ring 68. The dust ring 68 discourages re-entrainment of the separated dirt and dust back into the airflow. When the fine dirt and dust has been separated from the airflow, the cleaned air exits the cyclonic separator via the vortex finder 54 and passes through the fan and motor unit 50 so as to cool the motor before being expelled to the atmosphere.

The fin 78 discourages uneven accumulation of dirt and fluff particles and helps to distribute the dirt and fluff collected around the end of the bin 62 in a relatively even manner. It achieves this by the baffle 78 against which dirt and dust separated in the outer cyclone 58 can accumulate. The constant airflow within the bin 62 presses the separated dirt and dust against the baffle 78 and a build up of dirt and dust occurs. The location of the fin or baffle 78 at an uppermost point within the bin 62 means that the initial build up of dirt and dust is located in that area. As the build up continues, the accumulated dirt and dust builds up around the inner wall of the bin 62 and accumulation is relatively even and uniform.

As cleaning progresses, the accumulation of the dirt and dust within the cyclonic separator 52 progresses in the right hand direction as seen in Figure 2 until the level of the broken line D has been reached in the outer cyclone 58. At this point the level of dust and dirt at the lowest point of the cyclonic separator 52 has reached just beyond the lip 83 of the shroud 80 and the bin 62 is deemed to be full. If cleaning continues and more dust and dirt enters the cyclonic separator 52, then the level of dirt indicated by the broken line D will progress further to the right until that line touches the lip 83 of the shroud 80 in the outer cyclone 58. In this event, the risk of dirt and dust becoming re-entrained into the airflow and passing out of the vacuum cleaner 10 and into the atmosphere is increased. Furthermore, the risk of larger dirt and dust particles causing partial blockage of the shroud 80 which could in turn reduce the pick-up efficiency of the cleaner 10 is increased. At the same time, the level of fine dust in the collector 74 will have reached about the level of broken lines E1 and E2.

In Figure 2, reference numeral 103 represents the optical beam of a detector according to the invention which detects when the bin is deemed to be full and, as can be seen, is located just on the lower part of the broken line D of the collected dust and dirt. The presence of the device allows the vacuum cleaner 10 to be left to operate unsupervised without the user needing to return to the appliance periodically to check whether the dirt and dust container requires to be emptied. Nor is there any risk that the appliance will become full and continue to operate at a reduced performance level, which could lead to dissatisfaction on the part of the user and frustration that the area thought to be clean must be cleaned again.

The circuit shown in Figure 4 comprises the two rechargeable batteries 46, a battery and motor management system 41, a motor 50 for driving a suction fan, motors 43 for driving the left and right hand wheels 14 of the vacuum cleaner, a motor 28 for driving the brush roller 26 of the vacuum cleaner, processing circuitry 23 (which includes a microprocessor and field programmable gate arrays), left and right hand sensor interfaces 25 and 27 respectively, a user interface board 29 and a light detector 17. The light detector 17 detects light received from a plurality of compass points around the vacuum cleaner and is more particularly described in our International Patent Application WO 00/38027.

The plurality of movement control sensors are all designated by reference 40 and are coupled to the processing circuitry 23 and to the right and left hand sensor interfaces 25 and 27. Further description of the method by which the vacuum cleaner 10 is navigated about a room to be cleaned is not necessary here since these features do not form part of the present invention.

The bin full detector according to the invention will now be described with reference to Figures 3 to 5. Referring to Figure 3, the floor of the chassis 12 has a part-cylindrical central region 12A which is generally symmetrical about the axis 18 and has a radius of curvature generally conforming to the radius of curvature of the outer wall 64 of the

cyclonic separator 52. The cyclonic separator 52 thus fits snugly into the central region 12A when it is supported on the chassis 12. Mounted in the central region 12A of the chassis 12 on opposite sides of the axis 18, are an IR transmitter T and IR receiver R. Each of the transmitter T and receiver R is mounted on a rectangular holder TA, RA which has resilient clips TC, RC by which it is clipped onto the edges of corresponding rectangular apertures in the central region 12A of the chassis 12.

During operation of the vacuum cleaner, a beam 103 is emitted from the transmitter T to the receiver R. The beam 103 travels along an optical path which extends directly from the transmitter T to the receiver R. The optical path thus travels through the wall 64 and passes across part of the outer cyclone 58 before passing again through the wall 64 and arriving at the receiver R. The transparent or translucent bin 62 through which the beam 103 passes has little effect on the infrared beam (so long as the bin 62 is not full). The detector circuit comprises the infrared receiver R and the infrared transmitter T. The receiver R is coupled to a receiver control circuit 102 and the transmitter T is coupled to a transmitter control circuit 100 (see Figure 4) which are part of the processing circuitry 23 which in turn is coupled to the power management system 41. The user interface board 29 has user control buttons 44A, 44B and 44C. Control button 44A is an "on/off" button. Control buttons 44B are "speed selection" buttons and control button 44C is a "go/pause" button. When the on/off control button 44A is operated a first time to turn on the power, the guidance electronics, control electronics and the power management system 41 are powered up. At that point the power management system 41 will activate the transmitter control circuit 100 which will energize the infrared transmitter T. The transmitter T preferably has a beam angle of between 20° and 30° and the beam 103 is directed towards the infrared receiver R through the transparent bin 62. In this embodiment, the beam 103 passes through the bin 62 generally along a chord thereof. The infrared light is received by the receiver R and the receiver control circuit 102 will signal to the processing circuitry 23 that the cleaner can be operated. The processing circuitry 23 will also tell the user interface 29 to ensure that a bin-full indicator light L is off. The user can then press the "go" button 44C and the cleaner will operate. If

sufficient dust has collected in the bin 62 to cause the amount of dirt and dust therein to build up to the level of the beam 103 as shown in Figure 2, the infrared beam will be prevented from reaching the receiver R. The receiver control circuit 102 will then signal to the processing circuitry 23 to stop the cleaner if it is operational, or to prevent it from being started. It will also signal to the user interface board 29 to illuminate the bin-full indicator light L on the main body of the cleaner 10 so that the user becomes aware of the reason why the cleaner 10 cannot be operated or has stopped. The reason will be that the bin 62 needs emptying.

In operation the cyclonic separator 52 will, within the outer cyclone, rotate larger pieces of dust and fluff at a generally regular speed (perhaps around two or three circuits per second) around the periphery of the bin 62 before these pieces collect towards the left hand end of the bin 62. They will therefore intermittently interrupt the light beam 103 during normal operation even though the bin 62 is not full or may even be essentially empty. Therefore, the processing circuitry 23 is programmed to accept pulsating-type signals from the receiver R, ie. will tolerate intermittent and irregular interruptions of the beam 103, and will await until a prolonged low-level signal for a predetermined period of time before it will signal to the power management system 41 to switch off the fan unit 50 and light the bin-full indicator light L. The predetermined period of time could be of any length but would probably be between 5 and 20 seconds, more probably 10 seconds. The amount of below-standard cleaning which will take place during an interval of this time is not significant.

It will be appreciated that processing circuitry 23 can be realised as a microprocessor under the control of appropriate control software 45 stored on a non-volatile memory, as an application specific integrated circuit (ASIC), as hardware circuitry, or in some other form.

In the present embodiment the invention is applied to a cyclonic vacuum cleaner where the dirt and dust is separated from the air by cyclonic action. However, it could be

applied to a vacuum cleaner in which dust and dirt is separated from the air by a filter element, provided that the container collecting the dust and dirt is transparent or at least has a transparent window on each side to enable the light beam to pass through the container.

In an alternative arrangement, the transmitter and receiver could be arranged so that the light from the transmitter passes across the container and is then reflected back to the receiver, which is arranged close to the transmitter. This is illustrated schematically in Figure 6A where the transmitter T and receiver R are located side by side and a reflector 200 is located on the remote side of the bin 62. The transmitter T transmits the light along path 201 through the bin to the reflector 200 which then reflects the light back through the bin 62 along the path 202. Alternatively, the reflector could be located inside the bin 62 so that the light beam only passes once through the wall of the bin 62 in each direction. This is shown schematically in Figure 6B. A further alternative arrangement has the reflector 200 positioned on the outer wall of the fine dust collector 74 with the transmitter T and the receiver R located on opposite sides of the bin 62 as shown in Figure 6C. It will be appreciated that one of the parts of the optical path 201, 202 will be arranged so as to intersect with the level of filling of the bin 62 which represents the "full" level at the location of the transmitter T and the receiver R.

It is particularly advantageous if the device is located on a level with the lip 83 of the shroud 80 so that there can be no possibility of the shroud 80 becoming clogged with dirt and dust. This would severely impair the operation of the vacuum cleaner 10. The level of dirt in the container is being sensed, in the present embodiment, just beneath the edge of the shroud of the cyclone. Because in this embodiment the cyclone is operating with its axis horizontal or nearly so, the dirt will collect in the container according to the shape generally indicated by the broken lines D,E1,E2 in Figure 2. Therefore in this embodiment the level of dirt is being sensed along a chord subtending an arc of about 60° to the axis 18, and less then 90° and the beam passes to one side of the inner cyclone

56. In an upright cyclone vacuum cleaner the level would be further away from the edge of the shroud than in the horizontal cyclone.

A particular advantage of the arrangement described above is the fact that the transmitter T and the receiver R are positioned outside the airflow path and do not therefore come into contact with the dirty air passing through the vacuum cleaner. This means that the transmitter T and receiver R do not require constant cleaning and other maintenance associated with their presence in a dirty environment. If the outer wall 64 of the bin 62 becomes dirty at a known rate, the power management system 41 can be programmed to allow for predictable differences and this will reduce maintenance and costs.

Claims

1. A vacuum cleaner comprising a dirty air inlet, a cleaned air outlet, an airflow path extending between the inlet and outlet, a dirt and dust separator positioned in the airflow path, a suction fan for drawing air along the airflow path from the dirty air inlet to the cleaned air outlet via the dirt and dust separator, a housing for supporting the separator and a device for detecting and indicating when the amount of dirt collected in the dirt and dust separator has reached or exceeded a predetermined level, wherein the device comprises an optical transmitter for generating an optical beam and an optical receiver, the optical transmitter and optical receiver being located on the housing at opposite ends of an optical path extending through the wall of the dirt and dust separator.

2. A vacuum cleaner according to claim 1, wherein the optical transmitter and optical receiver are positioned close to spaced-apart portions of the dirt and dust separator.

3. A vacuum cleaner according to claim 1 or 2, wherein the dirt and dust separator comprises a cyclonic separator.

4. A vacuum cleaner according to claim 2 or 3, wherein the cyclonic separator comprises a container in which the dirt and dust separated from the airflow by the cyclonic separator is collected, and the container has transparent or translucent walls adjacent the optical transmitter and the optical receiver.

5. A vacuum cleaner according to claim 4, wherein the container is made wholly from a transparent or translucent material.

6. A vacuum cleaner according to any one of claims 3 to 5, wherein the cyclonic separator comprises two cyclones arranged in series, each cyclone having a separate

container in which dirt and dust separated by the respective cyclone is collected, the optical path of the device being arranged to pass through only one of the said containers.

7. A vacuum cleaner according to claim 6, wherein the optical path of the device is arranged to pass through the container which is designed and adapted to collect a higher proportion of relatively large dirt and dust particles.

8. A vacuum cleaner according to any one of claims 3 to 7, wherein the cyclonic separator has a longitudinal axis and is arranged so that the longitudinal axis lies generally horizontally when the vacuum cleaner is in use.

9. A vacuum cleaner according to claim 8, wherein the optical path of the device is arranged to pass through the container below the longitudinal axis of the cyclonic separator.

10. A vacuum cleaner according to any one of the preceding claims, wherein the device comprises a light for indicating when the amount of dirt collected in the dirt and dust separator has reached or exceeded a predetermined level.

11. A vacuum cleaner according to any one of the preceding claims, wherein the detecting and indicating device is arranged to detect a change in the optical beam indicative of a predetermined level of collected dirt and dust having been reached or exceeded in the separator.

12. A vacuum cleaner according to claim 11 wherein the detecting and indicating device is arranged to detect a break in the optical beam which persists for a predetermined period of time.

13. A vacuum cleaner according to any one of the preceding claims, wherein the detecting and indicating device is arranged to shut down the suction fan when the

amount of dirt collected in the dirt and dust separator has reached or exceeded a predetermined level.

14. A vacuum cleaner according to any one of the preceding claims, wherein the vacuum cleaner is an autonomous vacuum cleaner.

15. A method of operating a vacuum cleaner comprising a dirty air inlet, a cleaned air outlet, an airflow path extending between the inlet and outlet, a dirt and dust separator positioned in the airflow path, a suction fan for drawing air along the airflow path from the dirty air inlet to the cleaned air outlet via the dirt and dust separator, a housing for supporting the separator and a device for detecting and indicating when the amount of dirt collected in the dirt and dust separator has reached or exceeded a predetermined level, the device comprising an optical transmitter and an optical receiver located on the housing, the method comprising the steps of passing an optical beam through the wall of the dirt and dust separator, detecting a change in the optical beam indicative of a predetermined level of collected dirt and dust having been reached or exceeded in the separator and providing to the user an indication of the predetermined level having been reached or exceeded.

16. A method according to claim 15, wherein the indication comprises the step of shutting down the suction fan.

17. A method according to claim 15 or 16, wherein the step of detecting a change in the optical beam indicative of a predetermined level of collected dirt and dust having been reached or exceeded in the separator comprises the detection of a break in the optical beam which persists for a predetermined period of time.

18. A method according to claim 17, wherein the predetermined period of time is between 5 and 20 seconds.

19. A method according to claim 18, wherein the predetermined period of time is substantially 10 seconds.

20. A vacuum cleaner or a method of operating a vacuum cleaner substantially as described herein with reference to the accompanying drawings.

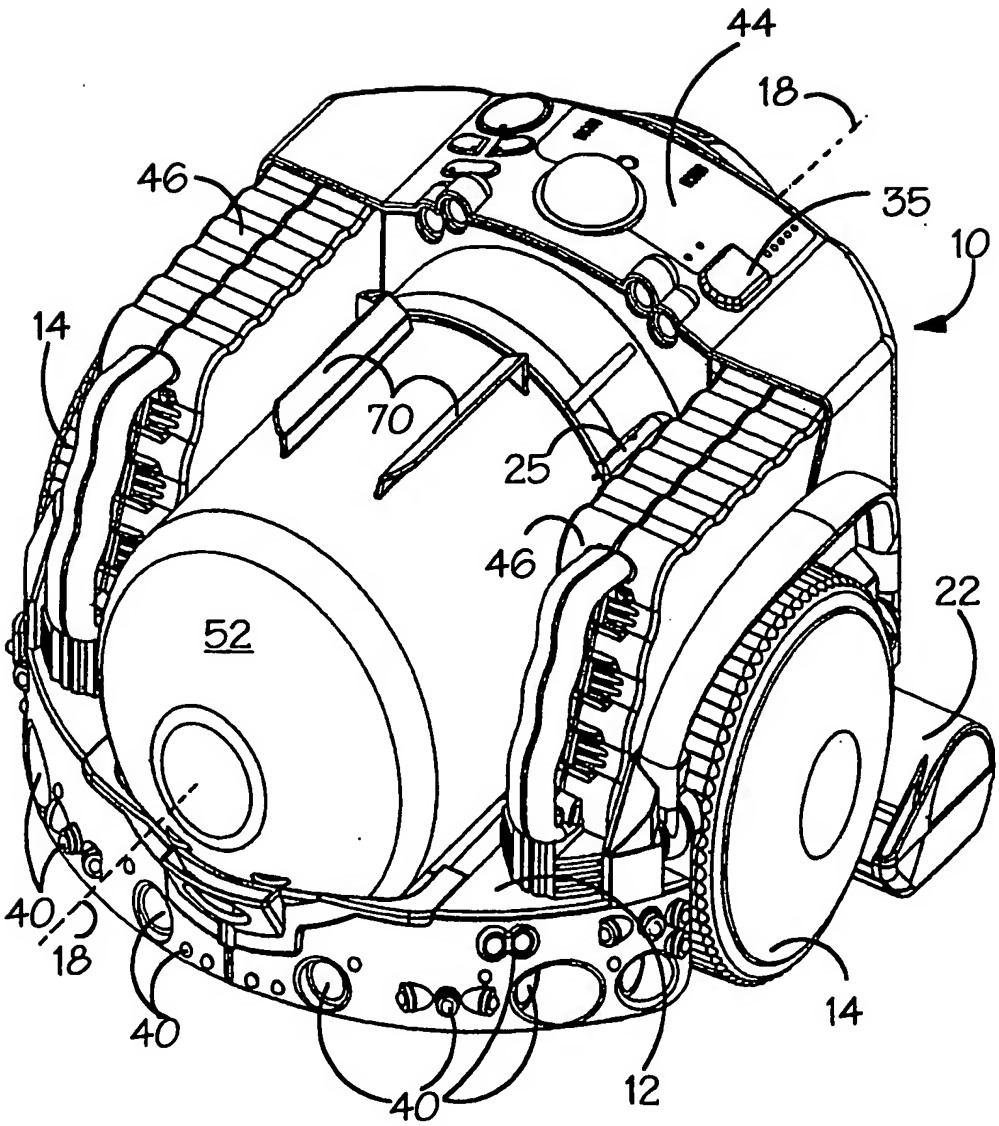
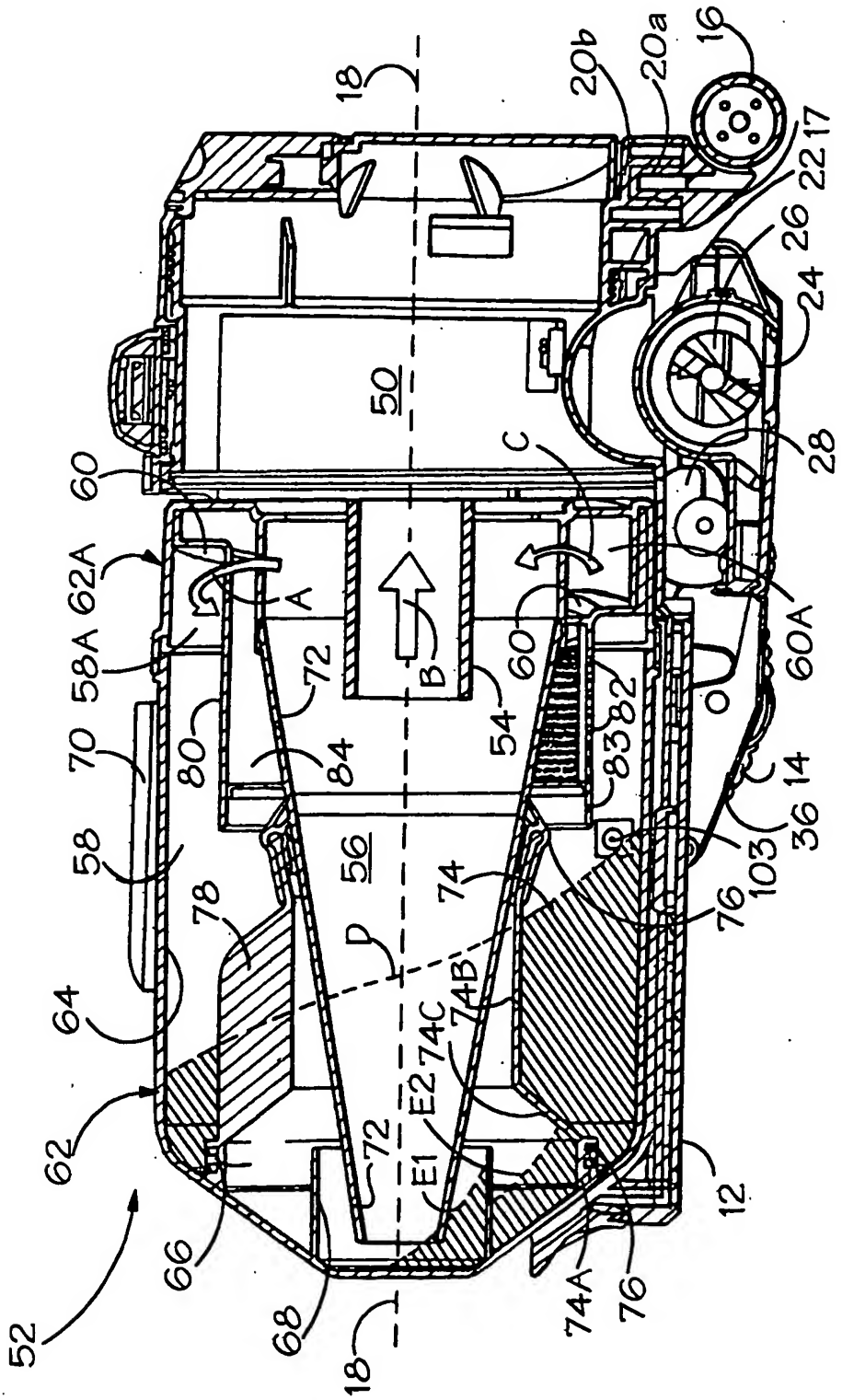


FIG.1.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60A
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80
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58
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74
76
103
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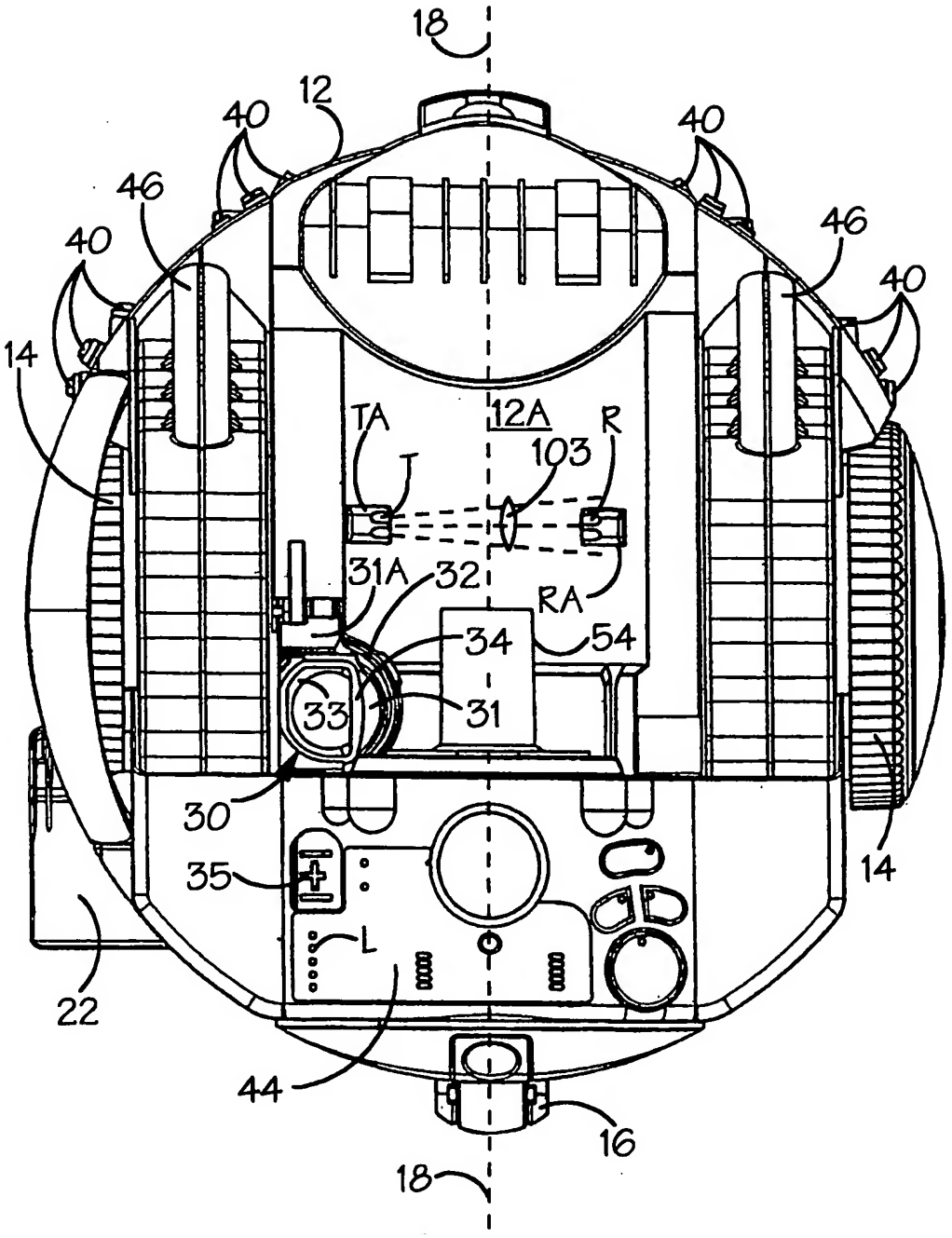
FIG.2.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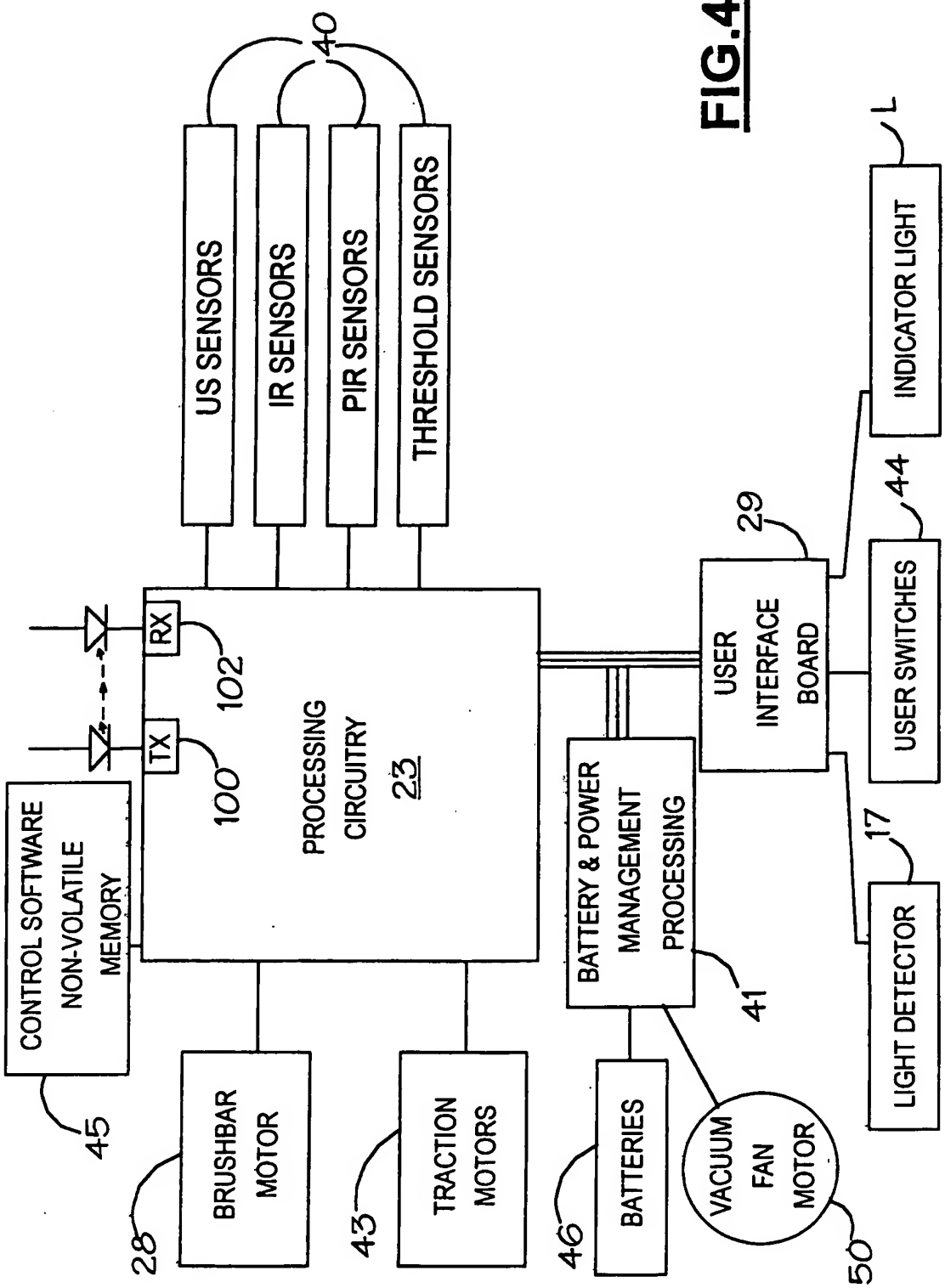
14

FIG.3.

FIG.4.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PIR SENSORS
THRESHOLD SENSORS
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TX
102
100
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23
CONTROL SOFTWARE NON-VOLATILE MEMORY
45
BRUSHBAR MOTOR
28
TRACTION MOTORS
43
BATTERY & POWER MANAGEMENT PROCESSING
41
BATTERIES
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VACUUM FAN MOTOR
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USER INTERFACE BOARD
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USER SWITCHES
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LIGHT DETECTOR
17

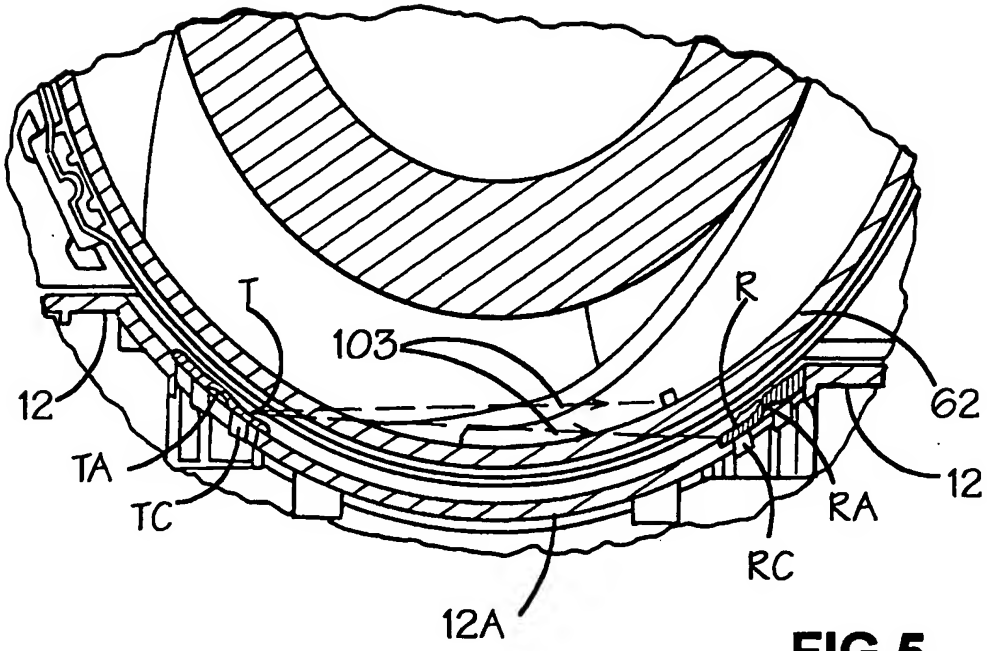


FIG.5.

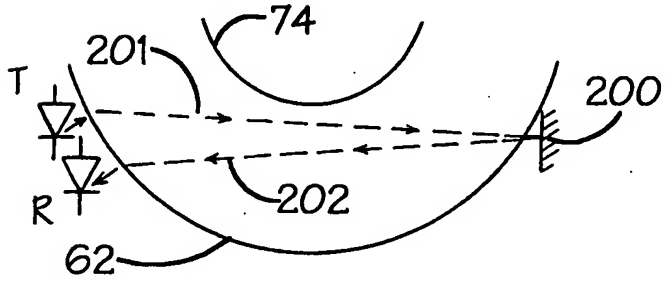
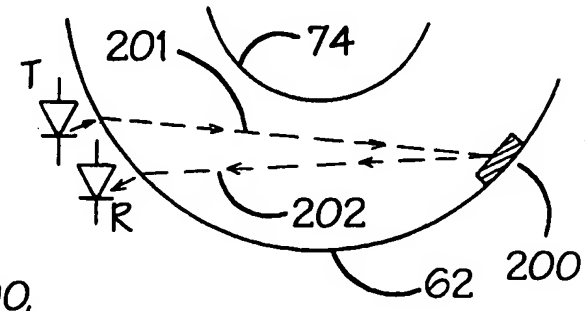


FIG.6A.

FIG.6B.



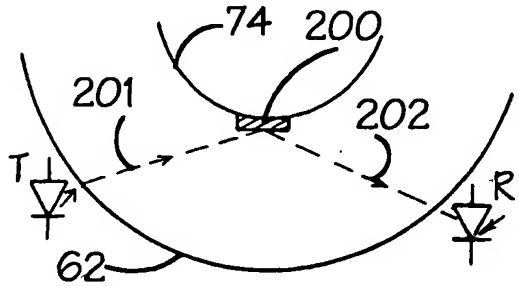


FIG.6C.

INTERNATIONAL SEARCH REPORT

Inter onal Application No
PCT/GB 00/02816

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A47L9/28 A47L9/19

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 A47L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	FR 1 150 184 A (FILLERY G T) 8 January 1958 (1958-01-08) the whole document	1,2,5, 10,11,15
Y		3,8,14
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 063 (C-0685), 6 February 1990 (1990-02-06) & JP 01 285236 A (MATSUSHITA ELECTRIC IND CO LTD), 16 November 1989 (1989-11-16) abstract figures 2,4,5	1,2, 10-13, 15-17

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[X] Further documents are listed in the continuation of box C. [X] Patent family members are listed in annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
11 October 2000	18/10/2000

Name and mailing address of the ISA	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Tx. 31 651 epo nl, Fax: (+31-70) 340-3016	Cabral Matos, A

1

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INTERNATIONAL SEARCH REPORT

Int: ional Application No
PCT/GB 00/02816

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	PATENT ABSTRACTS OF JAPAN vol. 016, no. 194 (C-0938), 11 May 1992 (1992-05-11) & JP 04 028322 A (TOKYO ELECTRIC CO LTD), 30 January 1992 (1992-01-30) abstract figure 1	1,2, 10-12, 15,17
X	DE 29 00 433 B (VORWERK & CO INTERHOLDING GMBH) 26 June 1980 (1980-06-26) column 2, line 12 - line 68 figure	1,2,10, 11,15
X	PATENT ABSTRACTS OF JAPAN vol. 014, no. 215 (C-0716), 8 May 1990 (1990-05-08) & JP 02 049621 A (MATSUSHITA ELECTRIC IND CO LTD), 20 February 1990 (1990-02-20) abstract figures 1,2	1,2,11, 15
Y	US 2 405 625 A (WHITON L C ET AL) 13 August 1946 (1946-08-13) column 2, line 24 -column 3, line 16 figures	3,8
Y	EP 0 803 224 A (ELECTROLUX AB) 29 October 1997 (1997-10-29) abstract figure 5	14

Form PCT/ISA/210 (continuation of second sheet) (July 1992)

INTERNATIONAL SEARCH REPORT

Information on patent family members

Inter onal Application No
PCT/GB 00/02816

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DE 2900433 B	26-06-1980	NONE	
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EP 0803224 A	29-10-1997	SE 509317 C SE 9601576 A US 5781960 A	11-01-1999 26-10-1997 21-07-1998